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Present Status of the Vacuum System for the 7 MeV Proton Linac

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Vacuum pressure needed for beam acceleration at the ion linear accelerator has been attained and proton beam has already been successfully accelerated to 7 MeV. Evaluation of the vacuum system is performed and total Q-value is estimated to be 6.0×10^{-5} Torr-l/sec, of which leak and outgassing rate from the surface of the vessel are $\sim 4.0 \times 10^{-5}$ Torr-l/sec and $\sim 2.0 \times 10^{-5}$ Torr-l/sec, respectively. From the mass spectrum of the residual gas, no peak of hydro-carbon was observed.

KEY WORDS: Q-value/ Leak/ Outgassing Rate/ Conductance/ End Pressure

1. INTRODUCTION

At Accelerator Laboratory of Institute for Chemical Research, Kyoto University, 7 MeV proton linear accelerator composed of an RFQ and a DTL has been constructed and since January, 1992, proton beam has been successfully accelerated up to 7 MeV.¹⁾ Vacuum pressure in the linac cavity has already reached in the region of $\sim 10^{-7}$ Torr necessary for beam acceleration. Some improvements in vacuum pumping system have been already reported.¹⁾ A roughing pump of the linac cavity is recently replaced so as to reduce the needed time and an evacuation system for the high energy (7 MeV) beam transport line is to be newly added at the emittance monitor. In the present paper, these recent improvement is described together with the result of the evaluation of the performance of the evacuation system at the RFQ and DTL.

2. EVACUATION SYSTEM OF THE LINAC CAVITIES

The vacuum pressure in the ion accelerator should be so good enough as the loss rate of the accelerated ions by the collision with the residual gas molecules is negligibly small. It can be estimated from the mean free path of the accelerated ions. Further the vacuum pressure is required to be so good as enough power of RF for the beam acceleration can be safely applied into the cavity. From this point of view, spark discharging in the vacuum vessel and multipactoring at the gap due to pollution of the material used for the cavity are to be taken into account. The vacuum pressure of the order of 10^{-7} Torr is especially necessary if H^{-} ions are to be accelerated in future. Further, the roughing pump with the pumping speed of 290 l/min for the DTL cavity is replaced by the one with the speed of 918 l/min as shown in Fig. 1. Thus the whole linac

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cavity can be evacuated by this pump from the atmospheric pressure to 0.1 Torr in ~ 10 minutes and the total sequence to start up the evacuation system including the turbo-molecular pumps is well adjusted to realize much quicker pumping-down time than ever.

For the purpose of extending flexibility of installation of various equipments for beam experiments with 7 MeV proton, a new evacuation system is to be added to the beam emittance monitor system in the high energy beam transport line (HEBT) as shown in Fig. 1 together with its specifications.

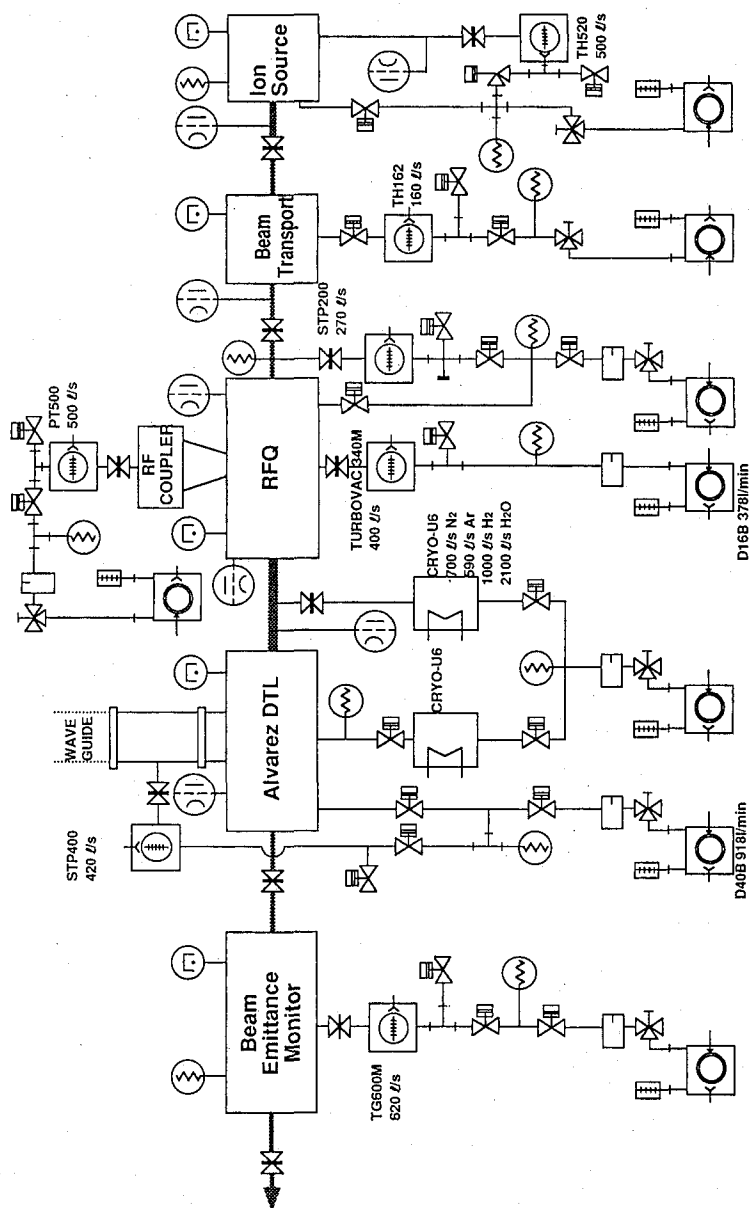


Fig. 1. Block diagram of the evacuation system for the proton linac at ICR.

3. EVALUATION OF THE VACUUM PUMPING SYSTEM

It is important to know the Q -value, conductance and effective pumping speed of the present evacuation system for the RFQ and DTL cavities from the point of view of maintenance of the system. The total Q -value including leak and outgassing rate is measured by studying the build up of the vacuum pressure after closing all the valves located in front of the pumps. The vacuum pressure is measured at four points by ionization gauges in a short period (~ 15 min.) after closing valves and then by Penning gauges. The build up characteristics (P vs t curves) in short and long terms are shown in Fig. 2(a) and (b), respectively. In the measurement of the data in Fig. 2(a), the same type of ionization gauges are used at RFQ Center and MEBT Center. Between DTL Center and RFQ End, also the same type of ionization gauges are used. However there is difference between above two groups. The discrepancy among two groups of data is considered to be due to such systematic error. From the measurement, total Q -value is estimated to be 6.0×10^{-5} Torr-l/sec in average. Total volume in the linac cavities is calculated to be 524 l. From the measured data shown in Fig. 2(b), Q -value at 10 hours after closing the valves is calculated to be 3.9×10^{-5} Torr-l/sec. As the gas absorption rate by the surface of the vacuum vessel increases when the vacuum pressure increases and finally make equilibrium with the outgassing rate of the surface, the measured Q -value long time after closing the valves is considered mainly due to the leak.²⁾ Thus the real outgassing rate from the surface is estimated to be $\sim 2.0 \times 10^{-5}$ Torr-l/sec.

Examples of the mass spectra of the residual gasses in the vacuum vessel after reaching the

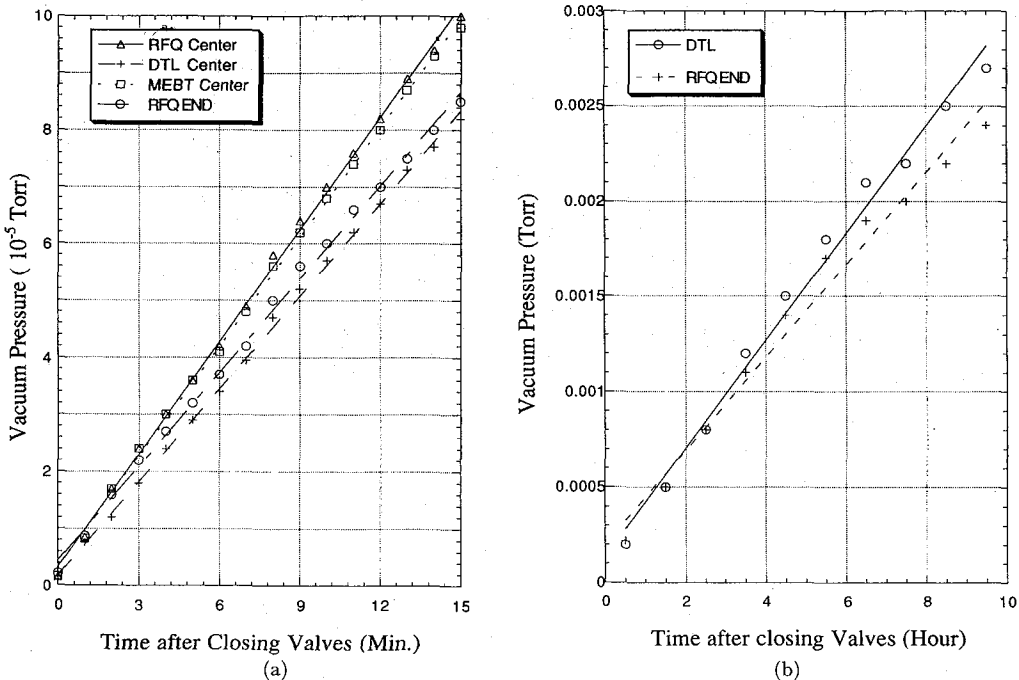
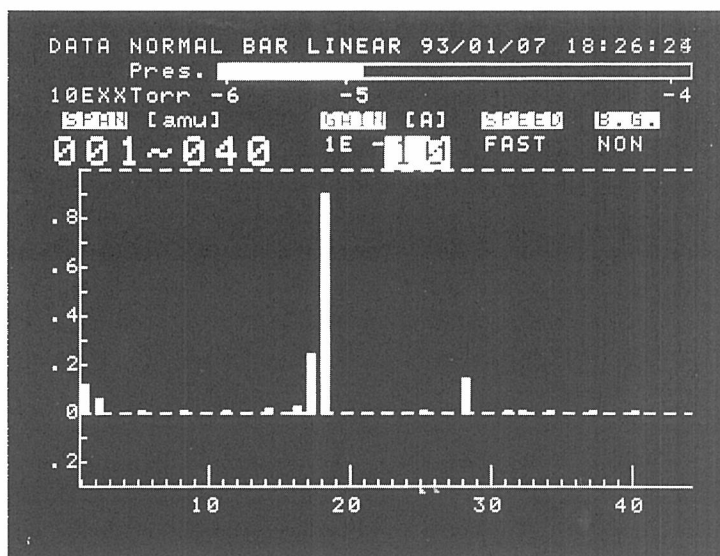
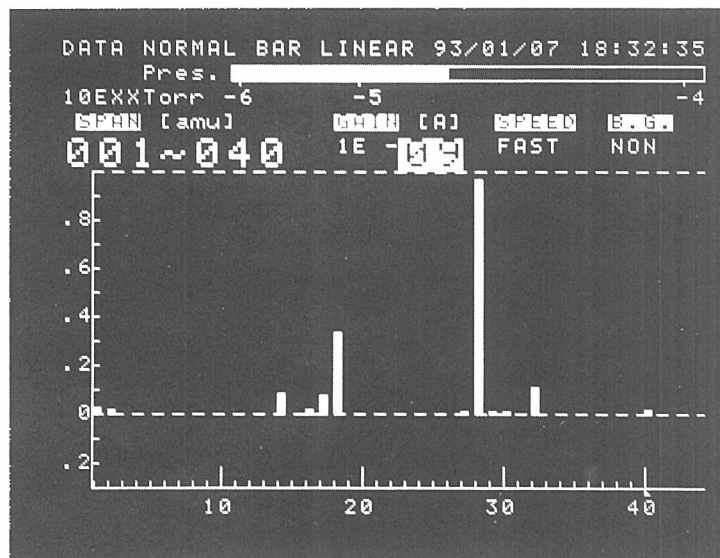


Fig. 2. Build up of the vacuum pressure in the cavity after closing all the valves in front of the evacuation ports. (a) and (b) represent the data in short and long terms, respectively.



(a)



(b)

Fig. 3 The spectra of the residual gas in the cavity after the end vacuum is attained. Data shown in (a) and (b) are taken with the conditions that (a) all the evacuation ports are active (b) all the evacuation ports are closed by valves.

end pressure are shown in Fig. 3(a) and (b) for the cases with and without pumping, respectively. Mass analysis was made by a mass filter (ULVAC, MASMATE-100). As is known from the spectra, the partial pressure of H_2O ($m/e=18$) is eight times larger than that of N_2 ($m/e=28$) with full pumping, which indicates the leak rate of the air is negligibly small compared with the outgassing rate from the surface of the vessel. On the contrary, the partial pressure of N_2 is five times larger than that of H_2O without pumping.

The end vacuum pressure is estimated for the evacuation systems attached to the RFQ and DTL. Utilizing the value of conductance at each evacuation port, effective pumping speed can be calculated and the expected end vacuum pressure are 4.8×10^{-7} Torr and 4.6×10^{-7} Torr at the center of RFQ and DTL, respectively. The measured values by ionization gauges are 7.0×10^{-7} Torr and 6.2×10^{-7} Torr at the RFQ and DTL, respectively. Thus the ratios of the measured value and estimated one are 1.5 and 1.4 at the RFQ and DTL, respectively, which seems in fairly good agreement. The above small differences are considered to be due to errors in estimation of conductances, the position difference between the ionization gauges and the evacuation ports and the difference of the sensitivity of the ionization gauge to H_2O and N_2 and so on, which is left for further more quantitative investigation.

4. SUMMARY

The present evacuation system of the ion linear accelerator has attained the designed end pressure of 10^{-7} Torr and the RF feeding of high power and proton beam acceleration have been successfully performed without trouble. The roughing pump is replaced by a powerful one and the roughing time is reduced to ~ 10 minutes and total evacuation time is also largely shortened. Effective pumping speed of each evacuation port is clarified with small ambiguity, which will help the maintenance of the vacuum system for the case of modification of the apparatus.

5. ACKNOWLEDGEMENT

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